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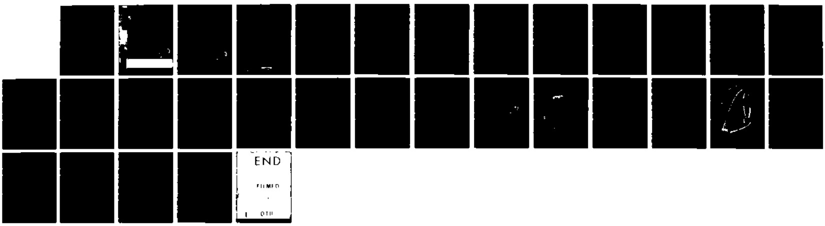

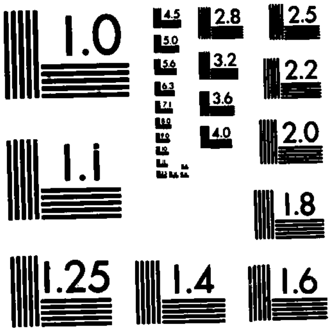

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This note contains a descriptive summary of shiphandling simulators with visual display capabilities. It contains a list of visual research issues which are suggested for investigation in order to define and develop a cost effective and useful shiphandling trainer.

PREFACE

This note contains a collection of data related primarily to visual display systems which are used on shiphandling bridge simulators. The data is intended to aid in the development of a Navy simulator.

The note may serve two purposes. First, it will inform the simulator design personnel of the variety of visual systems which are major components of existing and future bridge simulators and serve to explore various visual display alternatives. Secondly, it will suggest that design personnel consider the possibility of visual research in order to properly define the visual systems.

The writer wishes to give thanks to the Sperry System Management, Great Neck, N.Y., for their kind permission to use data from Sperry's Publication No. GB-20-1007, Table A-1.

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SECTION I

INTRODUCTION

The Navy is planning to obtain a Shiphandling Training System which will include an advanced shiphandling simulator. This simulator has been proposed as having a bridge mockup, instructor console, and an appropriate visual display system. The visual display system will be capable of presenting own-ship out-the-window visual scenes and simulated motion characteristics for selectable specific ship/classes.

One of the most difficult problems facing the shiphandling project team will be the determination of the visual display requirements, since little objective information is available that pertains to design and use of maritime visual simulation. A summary of visual display systems should assist the project team in the solution of this problem. Therefore, a literature review was made to collect and summarize data of visual display systems associated with current and future shiphandling bridge simulators. Also included are a description of the Navy Visual Technology Research Simulator (VTRS), a list of suggested Naval Vessels for the simulator, and some research data. Proposed visual research issues are listed in Appendix C.

The purpose of this note is to help reduce some of the required effort of the project team by providing information about available visual display systems and research data and, thereby, assist in the definition and/or development of a cost effective display to meet Navy training objectives.

SECTION II

SHIPHANDLING SIMULATORS WITH VISUAL DISPLAY

The summary consists of current and future shiphandling simulators with a visual display capability. The information was obtained from a variety of sources: literature review, conferences, and field trips. The displays described herein were designed to simulate the "off-the-bridge" scenario of a harbor or sea area environment as observed by the bridge officer. The displays are produced by different methods, namely, computer image generation (CIG), computer controlled multi-still projection slides, multi-spot projectors, motion picture film computer controlled images, and television and model board. These differences pertain to the training objectives and methodologies used by the different simulators (e.g., fundamental shiphandling training, emergency shiphandling training, collision avoidance training, and bridge team/organizational training). Many of these simulators are currently operational in the United States and in other countries. A number of future shiphandling simulators with visual display are under development, and most of them are scheduled to become operational in the very near future.

CURRENT SIMULATORS

Three shiphandling simulators, CAORF, MSI, and Ship Analytics, with visual display capabilities are currently operational in the United States and are first summarized. The display parameter and design features are listed in Table I. The Marine Safety Institute (MSI) and the Computer Aided Research Facility (CAORF) have been in service since 1975 and 1976 respectively.

CAORF has been called a sophisticated, state-of-the-art ship maneuvering simulator which was constructed by the U.S. Maritime Administration for the purpose of conducting controlled research studies of man-ship-environment interfaces. MSI is a commercial organization, and its simulator provides deck officers with hands-on training in ship piloting, maneuvering and docking. Since there was adequate information in the literature which functionally describes the CAORF and MSI simulators, a description of their major subsystems is provided in Appendixes A and B.

The U.S. expects to have two additional simulators in the future. One at the Marine Institute of Technology and Graduate Studies (MITAGS), Linthicum Heights, MD. Planned installation date is mid-1982. The other maritime simulator is in the planning stage and is being sponsored by the Marine Engineers Beneficial Association - Associated Maritime Officers (MEBA-AMO). Installation site is in Toledo, OH. Display description of the MEBA-AMO simulator is not available. MITAGS is described in future simulators.

World-wide operational shiphandling simulators are briefly described in Table 2.

FUTURE SIMULATORS

Three shiphandling simulators are presently under construction and are scheduled to be operational this year, 1982. These are briefly described in Table 3.

TABLE 1. OPERATIONAL SHIPHANDLING SIMULATOR IN THE UNITED STATES

Name	Computer Aided Operation Research Facility (CAORF)	Marine Safety International	Ship Analytics
Location	Kings Point, NY	Marine Terminal LaGuardia, NY	N. Stonington, CT
Manufacturer	Sperry	Sperry	Ship Analytics
User	Marine Administration	Commercial Masters & Deck Officers	Ship Analytics
Purpose	Research	Training	Demonstration Research
Capability	Open Ocean, Harbor Maneuvers	Open Ocean, Harbor Maneuvers, Restr. Waterways	Demonstrated Restr. Waterway
Maneuvering Area	50 X 100 nm	5 X 10 nm	Unknown
Bridge Size	20' W X 14' D	14' W X 14' D	14' W X 10' D
Projection Technique	5-Eidophor Seq. Color Projs	3-GE Monochrome Light Valves Projs	5 Color Projs
Display Features			
Field of View			
(1) Horizontal	240°	140°	180°
(2) Vertical	+10°, -14°	+10°, -14°	+10°, -14°
Image Source	Computer Gen. Image	TV/Model 1: 2000 15' X 30'	Computer Gen. Image
Brightness	5 ft.-L	2 ft.-L	Unknown
Resolution	8' arc min/lp	7.5 arc min/lp, H. 6 arc min/lp, V.	Unknown
Screen			
(1) Type	Front Proj. Cylindrical	Front Proj. Cylindrical	Rear Proj. Cylindrical
(2) Dia. X Ht	60 ft. X 12 ft.	50 ft. X 14 ft.	16 ft. X ? ft.
Motion Platform	None	None	None

TABLE 2. WORLD-WIDE OPERATIONAL SHIPHANDLING SIMULATORS

Name - Location	Designer - Supplier	Effects Simulated	Ships Simulated	Gaming Area	Visual Presentation	Limitations - Remarks
U.S. Maritime Admin. National Maritime Research Center, Kings Point, New York	Sperry Systems Management Div. Sperry Rand Corp; Jan '76; Research	Wind (shifts & gusts) Current Tug forces Shallow water Docking (within 50 ft.) Collision Avoidance Manfunctions	80,000 - 165,000 - 250,000 - 270,000 DWT Tankers; 15,000 DWT Cargo; 125,000 Cu Meter LNG	Visual: 50nm X 100nm Radar: 150nm X 200nm Open ocean, NY Harbor Valdez (50 X 50nm) Santa Barbara channel	Computer generated image (CGI); TV projection; color; Day or night; Fog; Nav aids, other ship traffic Topo features; own ship low 240 deg. Horiz.; +14 -10 deg. Vertical field of view	Stylized features and vessels in visual display. For additional information see Appendix A.
Marine Safety International Inc. La Guardia Marine Terminal, New York City, NY	Sperry Systems Management Div. Sperry Rand Corp; Jan '75; Training	Winds Currents Tug forces Water depth Passing & anchoring (index) Docking Malfunctions	30,000 - 250,000 DWT Tankers; 125,000 Cu Meter LNG Carrier	Visual: 5 X 10nm Radar: 10 X 15nm Open ocean, Milford Haven, Wales Ras Tannurah, Saudi Arabia Port Valdez, Alaska Chesapeake Bay & Savannah River; Elba Island LNG Dock	Changeable model boards; TV projection; monochrome; Day or night; Fog; Nav aids; clouds, detailed topo - cultural features; other ship traffic; own ship bow. 140 deg. Horiz. +10-14 deg. Vertical field of view.	Monochrome (coded flashing for buoy color) limited collision avoidance. For additional information see Appendix B.
German Academy of Nautical Sciences Bremen, W. Germany	VFW Fokker and Hochschule fur Nautik; Mar '75; Training	Winds Currents Water depth Anchoring Malfunctions	190,000 DWT Tanker 66,000 DTW Containership 22,000 DWT Cargo single/twin screw steam/diesel	Open sea to 39nm coastal; to 10nm; harbor 0.3 to 3nm	Still slides with landmass projector; projectors for sky, sea, Nav aids; flat screen 120 deg. horizontal field of view	No docking Limited maneuvering Limited No - Nav slides No controlled fog
Institute for Perception TNO Soesterberg, Netherlands	Institute for Mechanical Construction - TNO; 1976; Research	Winds Currents	Push-boat	Oude-Maas 2.8nm X 3.4nm Hartel Canal	Model board; point light source, TV projection; own ship bow; 120 deg. horizontal +10-20 deg. vertical field of view	Monochrome No night single model board No radar
Swedish State Shipbuilding Experimental Simulator, Gothenberg, 24 Sweden	Eng. Staff Chalmers University Gothenberg, Sweden; Oct '73; Research & Training	Winds Currents Tug Forces Docking (birdseye view)	15,000 - 350,000 DWT Ships; 265,000 DWT Tanker Twin/single screw Controllable pitch prop.	Europort-Rotterdam, Brofjorden-Sweden, Forshemmen-Gothenberg	Seven TV receivers in windows - simple topo features 80 deg. horizontal	Monochrome No night very simple radar
Ship Maneuvering Research Simulator; Institute TNO for Mechanical Construction; Delft, Holland	TNO - IWECO; Mar '70; Research & Training	Winds Currents Water depth Malfunctions	250,000 DWT Containership 545,000 DWT Tanker Twin Screw, Var pitch (Total 7 ships) 11.4' W X 9.8' D	6 X 6nm open sea 1.2 X 1.2nm harbor entrance	Models and shadowgraph, pt. light source, color or black/white, flat screw, 120 deg. horizontal (up to 360 deg. poss.)	No docking, no radar limited open sea No bank effects No other ships

TABLE 2. WORLD-WIDE OPERATIONAL SHIPHANDLING SIMULATORS (CONTINUED)

Name - Location	Designer - Supplier	Effects Simulated	Ships Simulated	Gaming Area	Visual Presentation	Limitations - Remarks
Netherlands Ship Model Basin (NSMB); Wageningen, The Netherlands	TNO-TWECO Delft Electronic Assoc; Sep '70; Research & Training	Winds, Fog Currents Shallow water Tug Forces Bank effects Malfunctions	45,000 DWT 250,000 DWT 20' W X 14' D	37 X 37 km	Shadowgraph, pt. light source, color or black/white, 2 projectors, 67 ft. dia. cylindrical screen, 240 deg. horiz. - land and bldgs colored shadows	No radar No docking No other ships
U.K. Dept. of Industry Naval Institute of Southampton	Decca Radar, Ltd. Walton-on-Thames England; Feb '76; Research & Training	Winds, Current Shallow water, Tug forces, Vibration, Radar malfunctions	253,000 DWT Tanker 80,000 DTW Container 18,000 DWT Cargo 125,000 Cu meter LNG	Lights for eight harbors or points	16 spot projectors, 100 deg. flat horiz. screen	Night only
Ishikawajima Heavy Industry Co., Ltd. Tokyo, Japan	IHI and NAC; 1975; Research & Training	Winds, Currents, Waves, Malfunctions, Target ships, Radar	200,000 DWT Tanker VLCC, ULCC, High Speed Container	0.3 to 8nm ocean, coastal and harbor	Slide projector system; 160° horiz., 30° vertical; day/night, fog, color, sea state, nav aids	No docking No tug forces No anchor forces
LMT Simulator Trappes, France	LMT, Div. Simulateurest Sys. Electronique; 1973; Training	Sea bottom, Wind, Waves	500 - 300,000 DWT Various types	20nm length channel or coastal	TV, models, CIG inset; color; 360° horiz.	No docking

TABLE 3. FUTURE SHIPHANDLING SIMULATORS

Name - Location	Designer - Supplier	Effects Simulated	Ships Simulated	Gaming Area	Visual Presentation	Limitations - Remarks
University of Wales Institute of Science and South Glamorgan Institute of Higher Education - Cardiff, Wales	Marconi Radar System (Visual System) - Leicester, England	Normal speed maneuvers; slow speed (docking) maneuvers; ship-ship interaction; tug forces; wind forces; vibration; own ship sound; textured and ripple seascape.	VLCC (1) Laden; VLCC (2) Laden and Ballast; 12,500 M^3 LND carrier; single-screw container ship; twin-screw container ship	Southampton Water Milford Haven	Computer Generated Image; 3 Color TV projectors; day or night; 120° horiz. X 30° vertical (expandable to 200° horiz.); 4m radius cylindrical screen	For training and research use. Full operational use in 1982.
Hamburg Polytechnic School of Maritime Studies - Hamburg, F.R. of Germany	Krupp Atlas Electronik - Bremen, F.R. of Germany	$\pm 5°$ roll and pitch hydraulic motion platform; time of day; visibility; winds; sea surface modulated in 5 stage from any direction; water depth	Total of 20 target ships, 5 closest displayed; 8 different type: Tug, Trawler, Coaster, Co-Ro Freighter, Ferry Container Vessel, LNG Carrier, VLCC	Visual: 94 X 94nm; German Bight, Isle of Heligoland, entrances to Wilhelmshaven and Bremerhaven, River Elbe waterway	Computer Generated Image; 11 color projectors; 250° horiz; 13m diameter cylindrical screen	For training and research use. Put into operation in mid-1982.
Marine Institute of Technology and Graduate Studies - Linthicum Heights, Maryland	VFW Fokker - Bremen, F.R. of Germany	$\pm$ 20° roll, $\pm$ 20° pitch and 18" heave hydraulic motion platform; shallow water; restricted waterways; heavy weather	160,000 DTW Tanker, Lash, Seabee, and Ro/Ro Vessel, 2 Container Ships, 20,000 DWT break bulk freighter and LNG Quincy design vessel	Areas to be determined. 40 ft X 60 ft model board photographed by a computer-controlled rotating camera	Computer controlled color film projection; day or night; 320° horiz. X 38° vertical; 50 ft radius spherical screen	For training purposes. Scheduled for completion in mid-1982.

SECTION III

VISUAL DISPLAY FACILITY AND DATA

The planned Navy Shiphandling Training System will be a prototype trainer. The definition of the visual display may require research; therefore, a research facility and simulation data may be required. Some of these have been summarized in this section.

Also provided in Appendix C is a list of visual display research issues containing most display methods, parameters, and contents which are associated with an off-the-bridge scenario. An examination of these issues is suggested for application; however, a training analysis would have already identified training objectives prior to this examination. Appendix D contains a table of proposed Navy surface vessels for simulation. The selection of these vessels were made without giving full consideration of training objectives, but is based upon the opinion of the Training Officer, SWOS, and because of the availability of data.

NAVY VISUAL TECHNOLOGY RESEARCH SIMULATOR (VTRS) FACILITY

In the event that a research facility is required to conduct visual investigations, one facility which may be considered for use is the Navy's VTRS which is located at NTEC, Herndon Annex. The facility display capabilities are summarized in Table 4.

Also, the following shiphandling simulation data are available for use and have also been integrated into VTRS:

1. Computer Image Generation Data Bases

   a. Attack Carrier, CVA-59, USS Forrestal

   b. Guided Missile Frigate, FFG-7, USS Perry

   c. Replenishment Oiler, AOR-1, USS Wichita

   d. Navy Vessel Berthing Area - Norfolk destroyer and submarine piers adjacent to Willoughby Bay and Hampton Road.

2. Navy Vessel Mathematical Model

   a. Destroyer, DD692, USS Gearing. The effects of wind, water depth, current and interaction effects between ships, may be simulated. Ship control console with engines and rudder command inputs is tied into system and available.

TABLE 4. NAVY VISUAL TECHNOLOGY RESEARCH SIMULATOR (VTRS)

Simulator	CTOL		VTOL
Location	NTEC, Herndon Annex		NTEC, Herndon Annex
Manufacturer	Singer/GE		Singer/GE
Purpose	Research		Research
Status	Operational		Assembly Underway (Operational 10/82)
Control Station	Navy T2C Fully Instrumented Cockpit w/ G-Seat		Navy SH-60B Full Scale Cockpit w/ G-Seat
Project. Technique	2 G.E. Color L.V. Projs (1-B.P., 1-T.P. w/10:1 zoom)		2 G.E. Color L.V. Projs
<u>Display Features</u>	<u>Background Proj.</u>	<u>Target Proj.</u>	
Field of View			
1. Horizontal	160°	60°/6.6°	160° (80° per proj.)
2. Vertical	+50°, -30°	40°/4.2°	+20°, - 50°
Image Source	Computer Image Generation		Computer Image Generation
Brightness	6 ft-L(BP)	6 ft-L(TP)	Not Available - Proj. output 650 lumens
Resolution	15 arc min/lp(BP) 12 arc min/lp(TP) 1.5 arc min/lp(TP) zoom		12 arc min/lp
1. Screen Type	Spherical		Spherical
2. Screen Diameter	20 ft		34 ft
<u>Motion Cueing</u>			
Motion Platform	6-DOF Synergistic		None
G-Seat	Pneumatic, 31 cells		Pneumatic, 8 cells

SECTION IV

SUMMARY

A total of thirteen shiphandling simulators, ten operational and three future, with visual display capability has been summarized. The image generator systems of the displays may be categorized into three types: computer image generation (CIG), terrain board television (TBTV), and photographic techniques (PT). The image generation systems of the operational simulators, consist of one CIG, four TBTV's and five PT's and the future systems will consist of two CIG's and one PT.

COMPUTER IMAGE GENERATION - CIG is considered to be the most flexible approach for a visual display system. Key elements of a CIG system are the off-line data base, display transformation, raster formatting and display. Current CIG designs are based upon software modelling, and the model may be duplicated without hardware implications. The data base may be readily changed in order to simulate different tasks. CIG systems have the flexibility to concentrate data at areas of greater interest and to vary details as a function of range. Color is also available because this feature can be stored in the data base, also the modeler has total control of contrast since CIG systems can create contrast within the computer. Multiple window displays may be provided for wide field of view with no risk and little complexity. Future developments will improve techniques for providing texture, contouring and other details required for lifelike imagery. These may be of particular importance to some shiphandling tasks which need the visual cues of ocean textures such as dynamic waves and ship's wake.

TERRAIN BOARD TELEVISION - The TBTV method of image generation may be considered the classic method. The main advantage is the real-world type imagery that is provided by the three-dimensional model. The TBTV cannot be matched where an accurate analog of the real world is a definite training requirement. Some problems which may be encountered with this system are the optical probe, bandwidth limitations of the video system, size of the model, and power dissipation of the model lighting.

PHOTOGRAPHIC TECHNIQUES - PT include the use of films, slides, and transparencies. Films provide the most direct means of real world modeling. Since they are usually taken at the optimum maneuver of the task to be simulated, films provide the best details over a wide range of viewing distance. Also wide angle field of view, high resolution and high brightness are available. Computer-controlled color slides is another PT which an optical mechanism is used to make changes in maneuvers. Point light sources (spot projectors) representing navigation color lights have been used and is limited to nocturnal scenarios. Installation of PT systems is relatively inexpensive as compared to TBTV and CIG systems, and the simplicity of design provides maximum reliability and maintainability. Disadvantages of the PT system are the very limited envelope in which the trainee could maneuver and the fixed third dimension. However, PT may be developed in the future for use in hybrid systems.

When reviewing the summary of shiphandling visual display systems and considering these or others for possible application towards a Navy shiphandling trainer, it is suggested that an initial effort should be to investigate and define what is

required of the system in order to effect transfer of training. Some questions to be answered such as what field of view, brightness and resolution are required to accomplish selected training tasks. Since real world duplication is technically difficult and costly it would be advantageous to define the training, simulation and hardware requirements, and thereby deliver to the Navy a cost effective and useful shiphandling trainer.

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APPENDIX A

DESCRIPTION OF CAORF

CAORF is a sophisticated ship-maneuvering simulator operated by the U.S. Maritime Administration for controlled research into man-ship-environment problems. The facility is located at the U.S. Merchant Marine Academy, Kings Point, N.Y., and has been in operation since 1976. Controlled experiments, which might require several vessels, cannot be performed readily in the real world and would certainly be ruled out for testing situations that involve potential danger. Such experiments can be performed safely and easily at CAORF. A simplified cutaway of the simulator building in shown in Figure A-1 and the relationships among the major subsystems are illustrated in Figure A-2. Additional system parameters and design features are shown in Tables 1 and 2.

All actions called for by the watch officer on the bridge are fed through a central computer that alters the visual scene and all bridge displays and repeaters in accordance with the calculated dynamic response of ownship and the environmental situation being simulated. CAORF has the capability of simulating any ship, port, or area in the world. Functional description of subsystems follows.

SIMULATED BRIDGE

The simulated bridge consists of a wheelhouse 20 feet wide and 14 feet deep. The equipment on the CAORF bridge is similar to that normally available in the merchant fleet and responds with realistically duplicated time delays and inaccuracies. The arrangement is based on contemporary bridge design. It includes:

<u>Steering Controls and Displays</u> - a gyropilot helm unit with standard steering modes, rate of turn indicator, rudder angle/rudder order and indicators, and gyro repeaters

<u>Propulsion Controls and Displays</u> - an engine control panel (capable of simulating bridge or engine room control), containing a combined engine order telegraph/throttle, an rpm indicator and a switch for selecting the operating mode such as finished with engine (FWE), warm up, maneuvering and sea speed.

<u>Thruster Controls and Display</u> - bow and stern thrusters and their respective indicators and status lights.

<u>Navigation Systems</u> - two radars capable of both relative and true motion presentations plus a collision avoidance system. Capability exists for future additions such as a digital fathometer, RDF (Radio Direction Finder), Loran C, and Omega systems.

<u>Communications</u> - simulated VHF/SSB radio, docking loudspeaker (talkback) system, sound powered phones and ship's whistle.

Wind Indicators - indicate true speed and direction of simulated wind.

CENTRAL DATA PROCESSOR

The central data processor computes the motion of ownship,models the behavior of all other traffic ships and drives the appropriate bridge indicators. Any ship may be simulated at CAORF. The computerized equations of motion are adapted to the ship by changing specific coefficients among which are hydrodynamics, inertial, propulsion, thruster, rudder, aerodynamic, etc. Wind and currents realistically affect ship motion according to draft (loaded or ballasted) and relative speed and direction. Ownship's computer model was validated by comparing various simulated maneuvers (e.g., zig-zag, turning circle, and spiral tests, crash stops and acceleration) with actual sea trial data.

IMAGE GENERATION

The visual scene is provided by a computer image generator and is projected onto a cylindrical screen. The visual scene is duplicated on CAORF to a degree of realism sufficient for valid simulation. The scene includes all the man-made structures and natural components of the surrounding scene that mariners familiar with the geographical area deem necessary as cues for navigation. Thus, bridges, buoys, lighthouses, tall buildings, mountains, glaciers, piers, coastlines, and islands would be depicted in the scene. In addition, the closest traffic ships and the forebody of ownship appear. All elements in the scene, except ownship's forebody, appear to move in response to ownship's and other ship's maneuvers. The sky is depicted without clouds and the water without waves.

For enhanced realism the scene is projected in full color. The perspective is set for the actual bridge height above waterline for the simulated ship. Shadowing can be varied according to the position of the sun at different times of day.

Environmental conditions also affect the scene. The lighting can be varied continuously from full sun to moonless night. At night, lights can be seen on traffic vessels, buoys, piers, and other points ashore. Visibility in day or night can be reduced to simulate any degree of fog or haze.

RADAR SIGNAL GENERATION

The Radar Signal Generator produces real-time video signals for driving the two radar PPIs. The items displayed are synchronized with the visual scene and include navigation aids, ships, shoreline and other topographical features with appropriate target shadowing, clutter, range attenuation, and receiver noise. The radar gaming area which covers an are of 150 by 200 miles, extends beyond the visual gaming area, which is 50 by 100 miles. Within the radar gaming area, as many as 40 moving traffic ships can be displayed. The radar signal generator also drives the collision avoidance system, which can be slaved to either of the master PPIs.

CONTROL STATION

The control station is the central location from which the simulator experiment is controlled and monitored. An experiment can be initiated anywhere within the

visual gaming area with any ship traffic configuration. The control station enables the researchers to interface with the watch-standing crew on the bridge, to simulate malfunctions, and to control the operating mode of the simulator. The Control Station is also capable of controlling motions of traffic ships and tugs in the gaming area and simulating telephone, intercom, radio (VHF/SSB) and whistle contact with the CAORF bridge crew.

HUMAN FACTORS MONITORING STATION

The Human Factors Monitoring Station is designed to allow collection of data on crew behavior. Monitoring data is provided by five closed-circuit TV cameras and four microphones strategically located throughout the wheelhouse to record all activities, comments and commands.

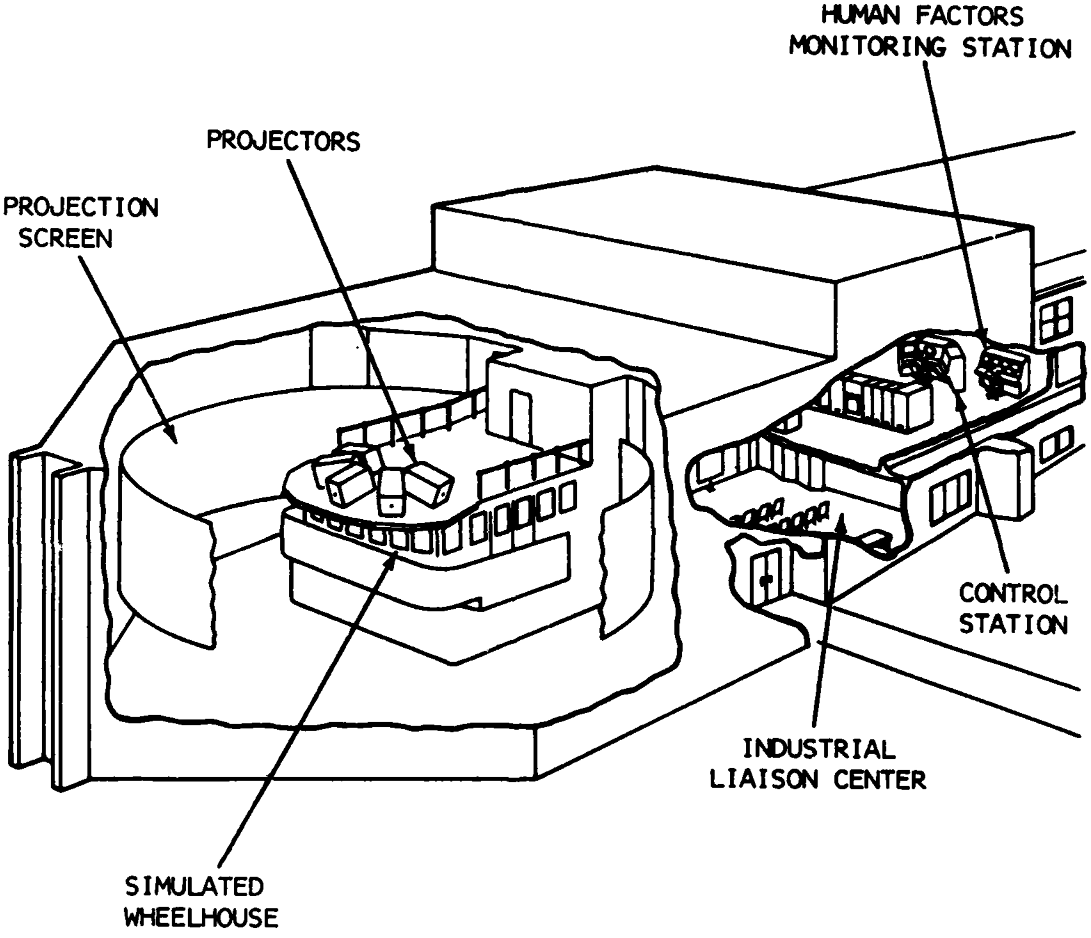

Figure A-1 Cutaway View of CAORF Building

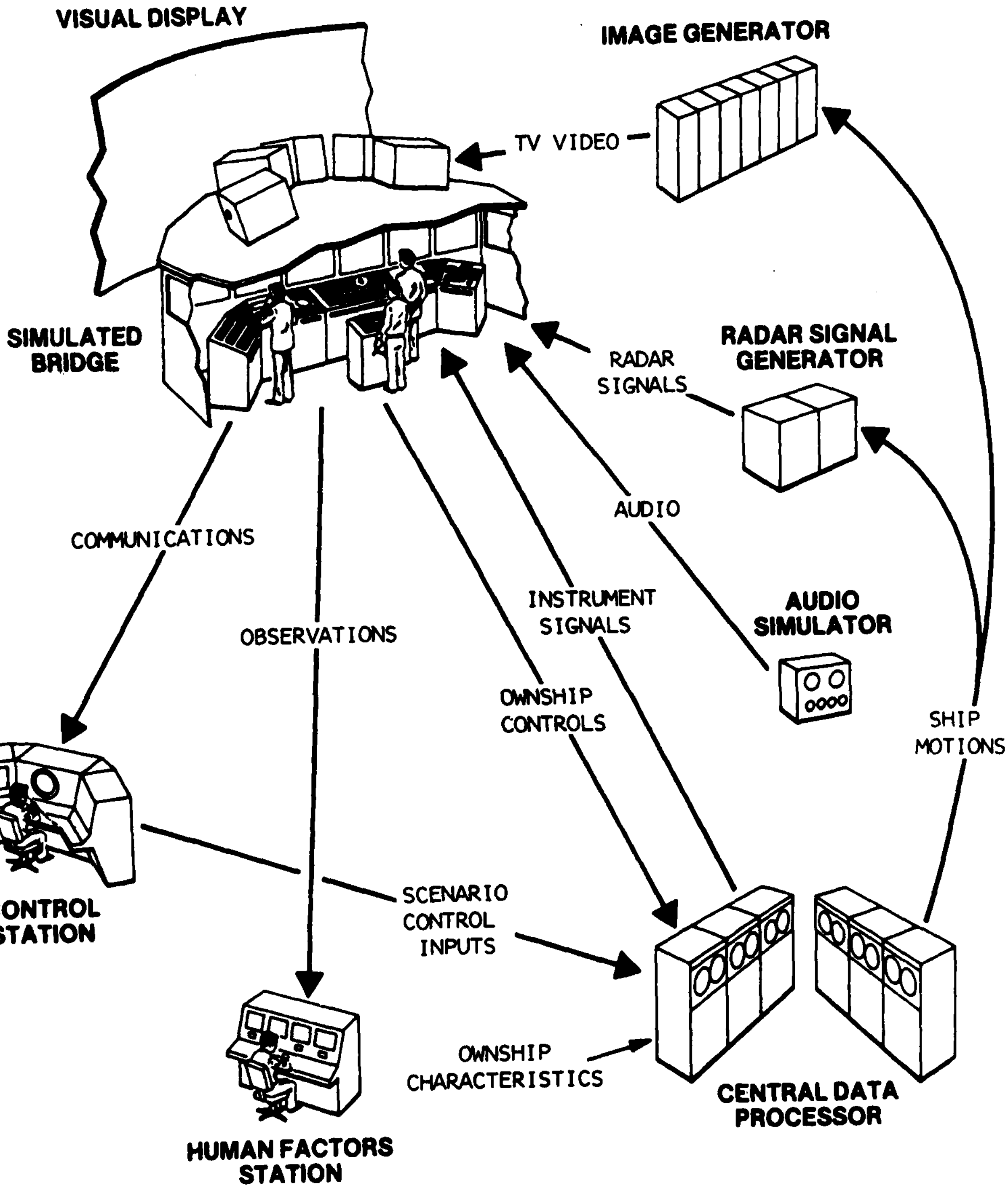

Figure A-2 CAORF Simulator Subsystems

APPENDIX B

DESCRIPTION OF MARINE SAFETY INSTITUTE SHIPHANDLING SIMULATOR

The Marine Safety Institute (MSI) *shiphandling simulator* was developed to provide deck officers with hands-on-training in ship piloting, maneuvering, and docking. It was installed at the Marine Air Terminal, La Guardia Airport, N.Y., and became operational in January 1975. The MSI facility can simulate the handling characteristics of a 30 thousand ton tanker, a 250 thousand DWT supertanker, and a 125 thousand cubic meter LNG carrier. Other ship types and classes may also be programmed. These ships are operated in precise reproductions of various harbors and approaches including Milford Haven, Wales, Ras Tannyrah, Saudia Arabia, and Port Valdez, Alaska. Navigation of the Chesapeake Bay, the Savannah River and docking at the Elba Island LNG Terminal may also be simulated.

The basic components of the MSI simulator include a simulated bridge, a visual scene display area, an instructor station terminal, a data processing and control subsystem, and an image generation area. Simulator operational parameters and design features are shown in Tables 1 and 2. The relationships among the subsystems are shown in Figure B-1 and a functional description of the subsystems follows:

SIMULATED BRIDGE

The simulated bridge consists of a walk-in wheelhouse with typical forward and side bridge windows. The wheelhouse is conventional in shape and of sufficient size (14 feet deep, 19 feet wide) to accommodate bridge instrumentation in a realistic layout and at the same time permit free movement of the trainee around the bridge. The perspective of the scene viewed from the bridge window is adjusted as a function of bridge height which is dependent on ship design and loading. Heights may be adjusted from 60 to 120 feet above the water.

IMAGE GENERATION

The image generation system provides a video image of the ship's operational environment. A pickup assembly consisting of an optical probe and three monochrome television cameras is carried by a computer controlled transport to scan a three dimensional scaled model board. The video signals of the model board are transmitted to the visual scene display which projects a wide angle scene forward of the bridge. Ownship fore deck image is generated by viewing a slide with an additional TV camera, and it is introduced into the scene by using video insertion techniques. Fore deck images may be changed to suit particular type and class of ship being simulated.

VISUAL SCENE DISPLAY

The visual scene display consists of three TV projector assemblies, mirror assemblies, and a cylindrical screen. This system provides a wide angle monochrome view of the maritime scene on the screen forward of the bridge. The color cues associated with navigation lights are simulated by modulating the intensity of the lights at frequencies that can be readily associated with a particular color. The display provides the view of the sea and land regions of

the gaming area, channel areas, buoys and navigation markers, coastline, docks, navigation obstacles, and hazards.

DATA PROCESSING AND CONTROL EQUIPMENT

This subsystem is composed of the central data computer system, the radar simulator, and the audio simulation equipment.

Computer System - The computer system consists of the central data processor, input/output devices, modems, and various peripherals. Also included are computer programs which accept inputs from the wheelhouse instruments and gantry, provide real time computation of ship motions resulting from their inputs and scale the resulting data to provide commands to all the subsystems in accordance with ship's heading and motion.

The computer is loaded with data on the hydrodynamic characteristics for the typical class of ship to be simulated. Detailed geographic, depth and water current information on the harbor or sea area to be simulated is separately loaded; thus, any ship can be used with any harbor. Using this intelligence, the computer causes the probe, bridge instruments and visual scene to respond in a real life manner. Computer software programs control steering, propulsion, bow and stern thrusters, gantry servos, wheel house instrumentation and sound effects.

Radar Simulation - The simulator provides bridge officers with a radar display coordinated with ship's position on the model board, other navigation instruments, and geographic and navigation aid features of the simulated harbor or sea area. The bridge radar is used precisely as at sea, and its operation is included in most training scenarios.

Audio Simulation - The audio simulation system provides normal environmental sounds into the bridge. These sounds include navigation aid sounds (buoybell horn, gong, and whistle), other ship whistles, ship propulsion, bridge noise, and background sea sounds. Bells and other sounds are provided directionally as a function of other ship contacts and decrease with range.

INSTRUCTOR STATION

The instructor station is the central location from which simulation exercises are controlled. The instructor can exercise management control over the visual and aural stimuli, ship malfunctions, the operating mode of the simulator and moving ships while monitoring simulator status as presented by the instructor station display. The station serves as the answering station for telephone, intercom, and radio contacts with the bridge. The station console houses all of the controls and displays needed to initiate, conduct, monitor and modify a training exercise or scenario.

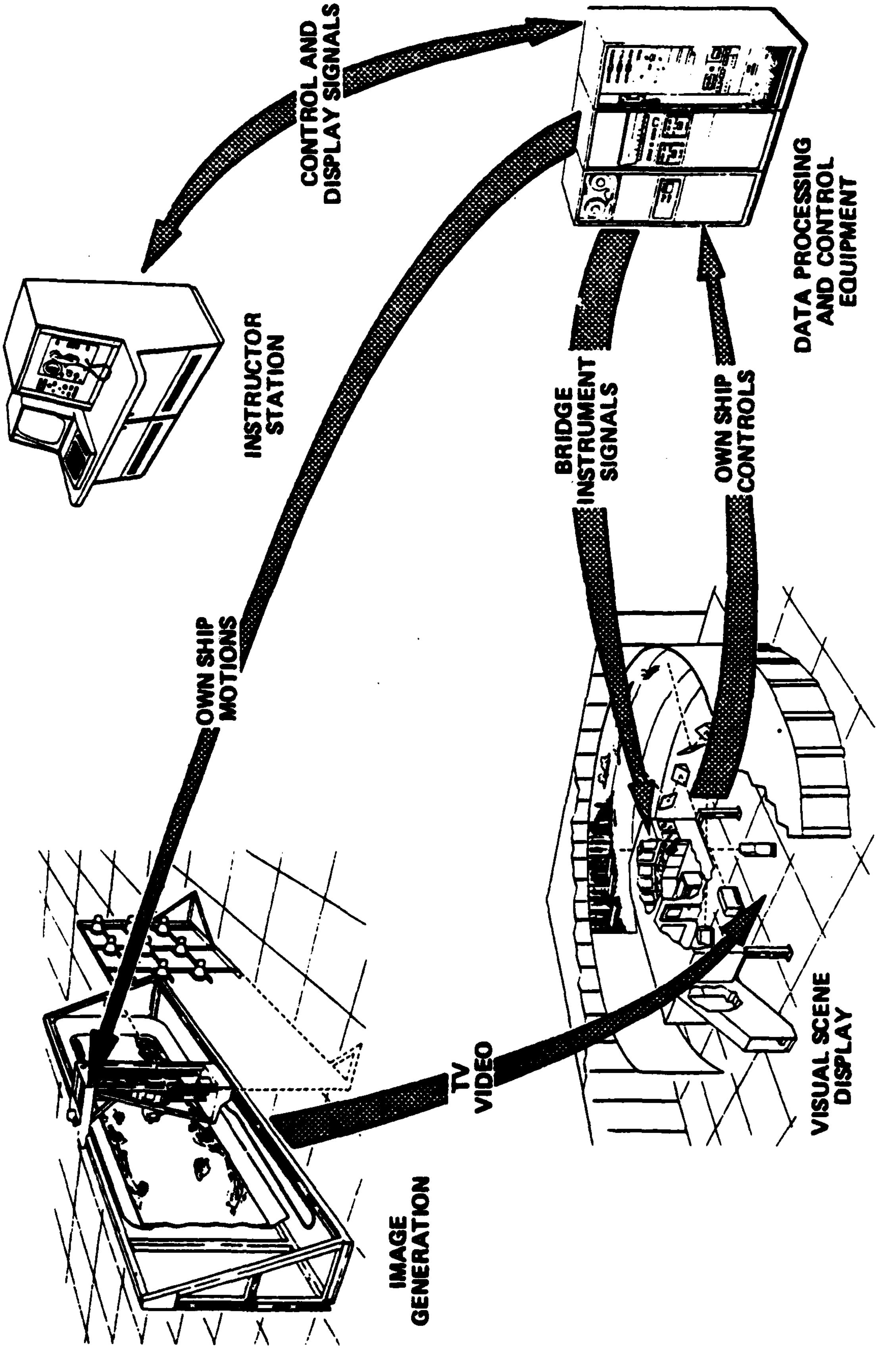

Figure B-1 MSI Shiphandling Simulator Subsystems

APPENDIX C

VISUAL DISPLAY RESEARCH ISSUE

The following statements provide probable research issues related to the visual display system compatibility for attaining the established training objectives.

Examine the relative effectiveness of:

Color vs. black and white

Varying degrees of horizontal and vertical field of view

Day vs. Night

Ship contact motion vs. stationary contacts

Symbol vs. other visual representation of contact aspect

Various numbers of ship contacts

Use of lights vs. shadow images in a nocturnal setting

Simulating own ship's motion (e.g., Pitch: $\pm 5°$, roll: $\pm 5°$, heave: ± 6 in.) and selecting the proper subsystem to be used in the simulation (e.g., visual vs. mechanical motion base)

Depth perception cues simulated by texture, black and white shading and color shading

Variable vs. fixed (e.g., zero or unlimited) visibility

Fast vs. real time

Bow wave and wake representations for visual cues for speed and direction of own ship and contact ship

The visual field vs. a mechanical motion base to represent own ship's motion.

Various sizes (e.g., less than 25 sq. mi., 25-625 sq. mi., and greater than 625 sq. miles), and types (e.g., open ocean, coastal waters, harbor waters) of exercise areas.

Various types of image projectors (e.g., slides, movies and TV) and image generation systems (e.g., model boards and computer-generated images).

APPENDIX C (cont'd)

Environmental factors (e.g., rain, fog and snow) to provide flexible scenario conditions.

Portraying actual vs. hypothetical harbors or ports.

A small vs. a large bridge, considering factors such as overall installation size, projection techniques, image clarity and parallex, and accommodation of required equipment.

Optical aids (e.g., binoculars and pelorus) vs. alternative information sources for information collection under varying full bridge simulator parameters (e.g., screen radius, image acuity, and image parallex).

Interactive effects of resolution, luminance, and contrast on image presentation.

Degree of richness (detail) of the visual field and the relative percentage mix of details (e.g., landmass, NAVAIDS, building structures) required to fulfill the training objectives.

Definition of the minimum range of effectively complete mooring and docking training objectives.

The effect on transfer of training of the selection of bridge configuration and components hardware.

The fidelity required for mathematical modelling of objects in the visual field.

APPENDIX D

PROPOSED NAVY SURFACE VESSELS FOR SIMULATION

TABLE D1. PROPOSED NAVY SURFACE VESSELS FOR SIMULATION

VESSEL	CHARACTERISTICS: FULL LOAD DISPLACEMENT (TONS)	CHARACTERISTICS: LENGTH x BEAM x DRAFT (FT)	CHARACTERISTICS: PROPULSION	MAXIMUM SPEED (KTS)	COMMENTS
CVA 59 "Forrestal" Class Carrier	75,900	1086 x 129.5 x 37	260,000 SHP 4 Shafts	33	a. Recommended by Director of Training, Surface Warfare Officer's School (SWOS) b. See Note # 1
DD 832 "Gearing" Class (FRAM I) Destroyer	3,520	390.5 x 40.9 x 19	60,000 SHP 2 Shafts	34	a. High utilization of this model to perform basic ship-handling training on Device 1DA6 at SWOS b. See Notes # 2 & 3
DD 963 "Spruance" Class Destroyer	7,810	563.2 x 55.1 x 29 (sonar) 19 (keel)	80,000 SHP 2 Shafts	33	a. Used on Device 1DA6 at SWOS
FFG-7 "Perry" Class Guided Missile Frigate	3,605	445. x 45 x 24.5 (sonar) 14.8 (keel)	41,000 SHP 1 Shaft	29	a. See Note # 1
FF 1052/1084 "Knox" Class Frigate	3,877	438 x 46.8 x 24.8 (sonar) 15 (keel)	35,000 SHP 1 Shaft	27	a. Recommended by Director of Training, SWOS. Also this ship model is moderately used for basic shiphandling on Device 1DA6 at SWOS b. See Note # 3
AOR-1 "Wi chita" Class Replenishment Oiler	37,360	659 x 96 x 33.3	32,000 SHP 2 Shafts	20	a. See Notes # 1, 2 & 3
AO 143 "Neosha" Class Oiler	38,000	655 x 86 x 35	28,000 SHP 2 Shafts	20	a. See Note # 3

NOTES:

1. Computer Image Generator (CIG) data for these vessels are being used at NTEC, Visual Technology Research Simulator Branch.

2. Math model for replenishment-at-sea simulation is documented from previous investigations. Model includes equations for ship dynamics, ship separation, interaction between supply ship and destroyer. Refer to NAVTRAEQUIPCEN IH-243.

3. Tactical characteristic reports of these vessels are listed as being available from David Taylor Naval Ship Research and Development Center. Refer to TAEG Report No. 65 for NSRDC Report numbers.

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